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Planetary Defense

Asteroids, Comets, Impact Craters, and Outwitting the Dinosaurs

Dr. Cathy Plesko

July 21, 2021

Los Alamos NATIONAL LABORATORY EST. 1943

NNSA National Nuclear Security Administration

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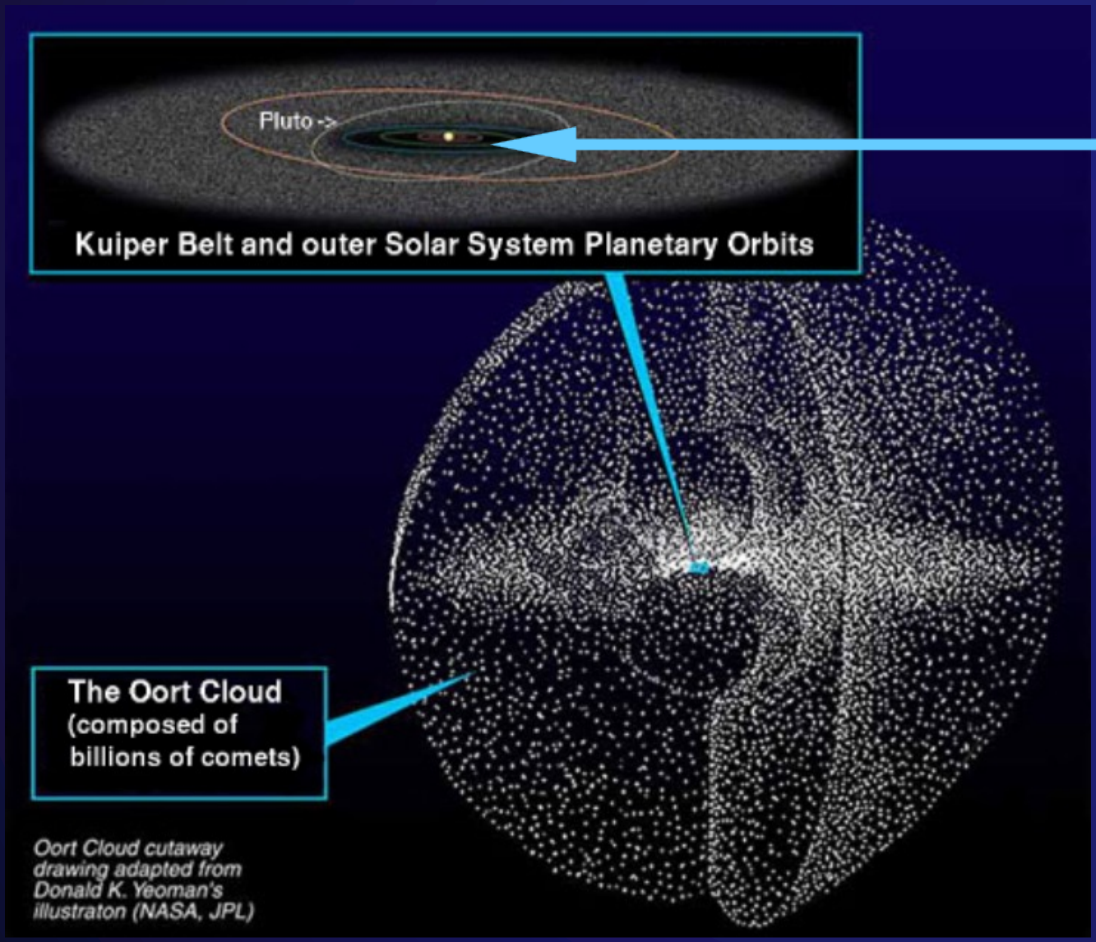
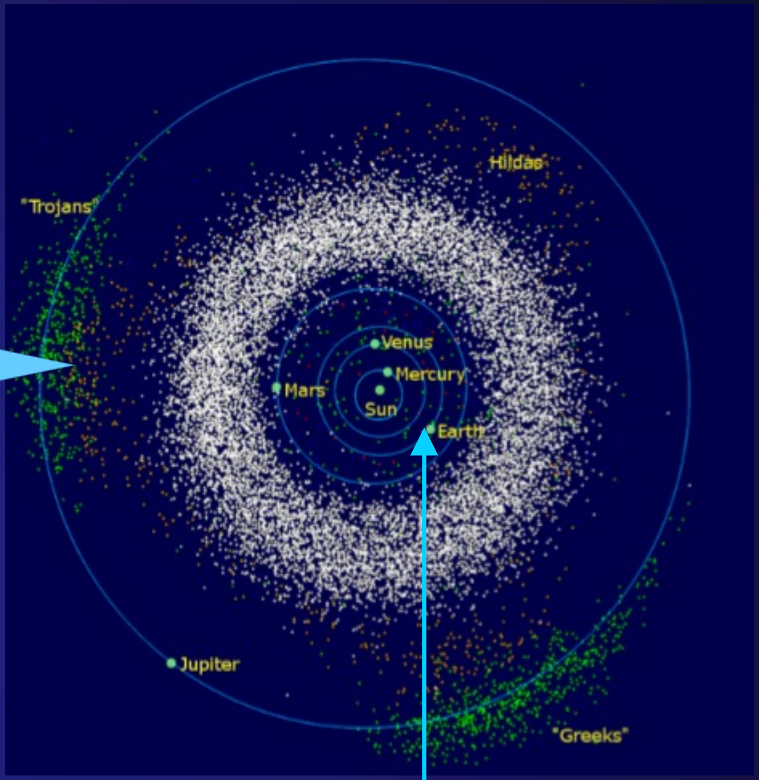
Our busy solar system





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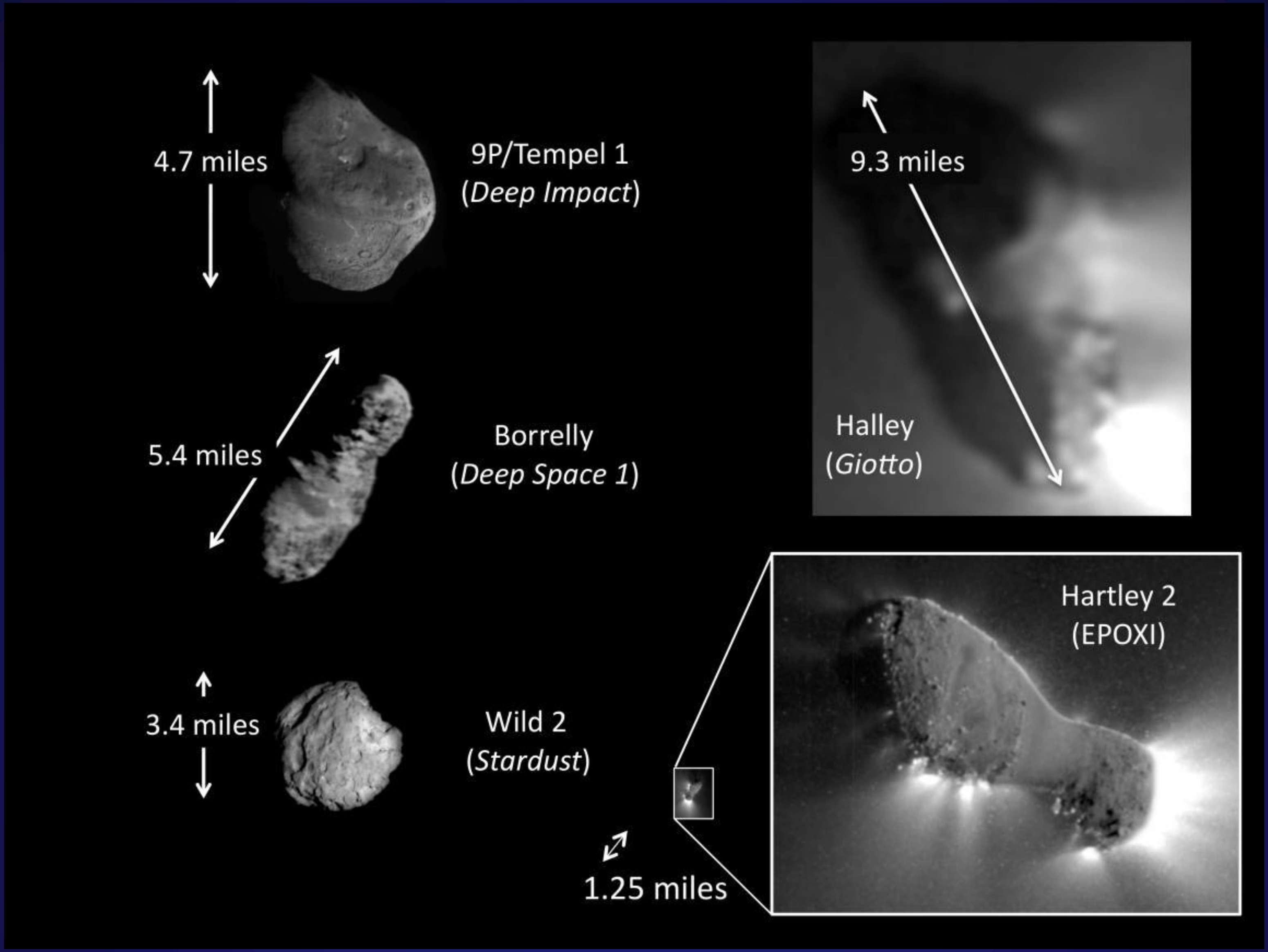
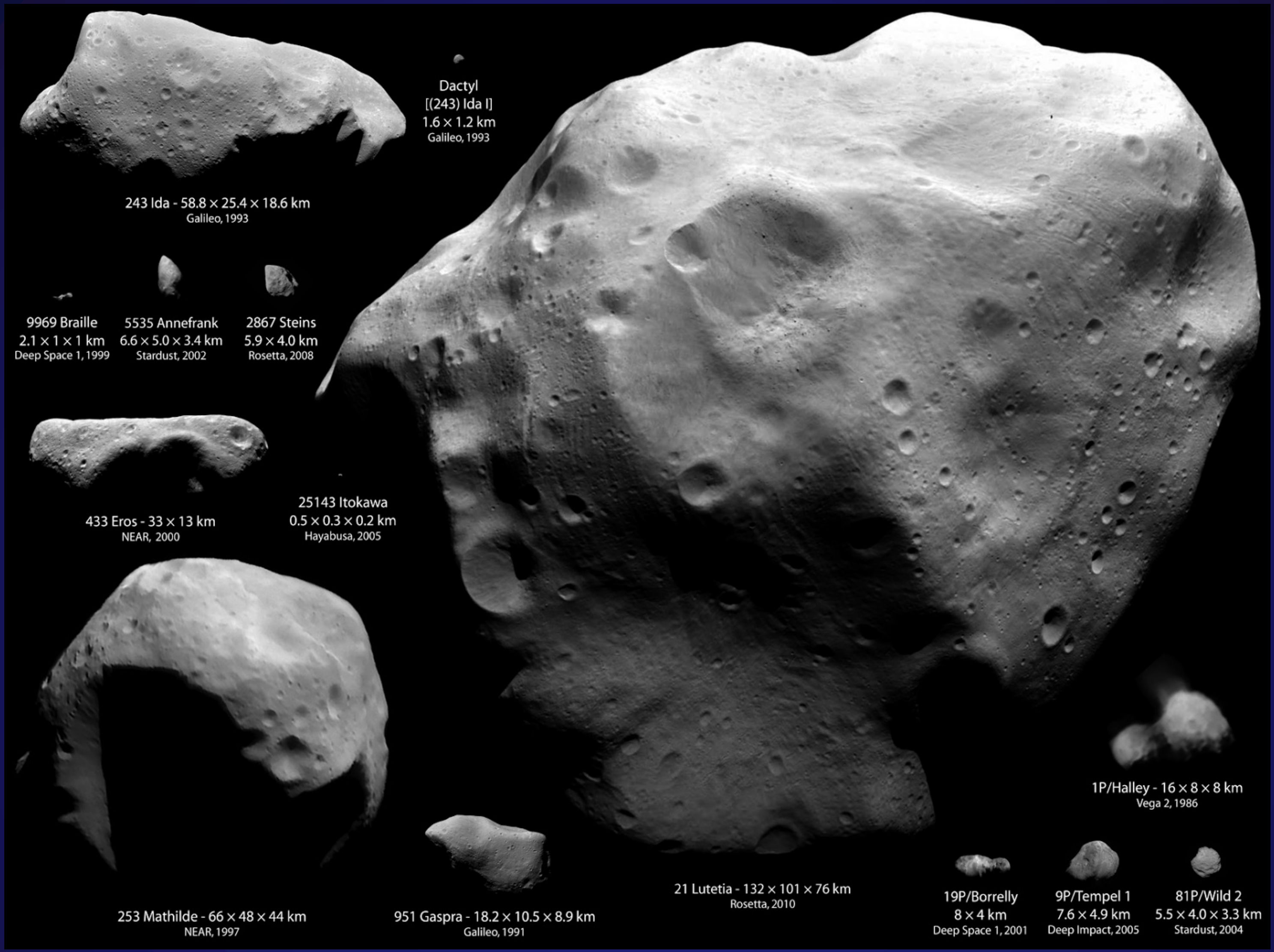
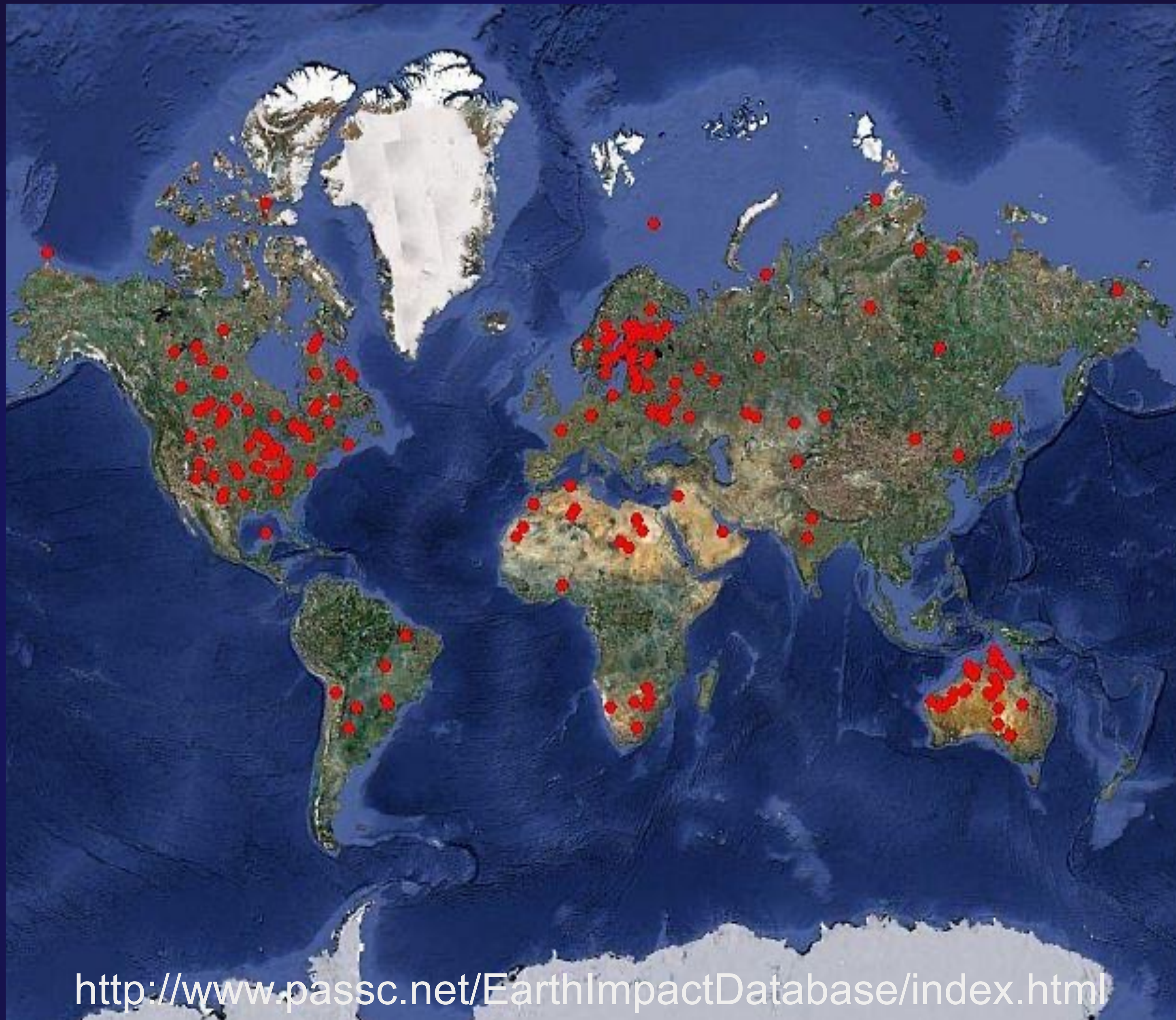


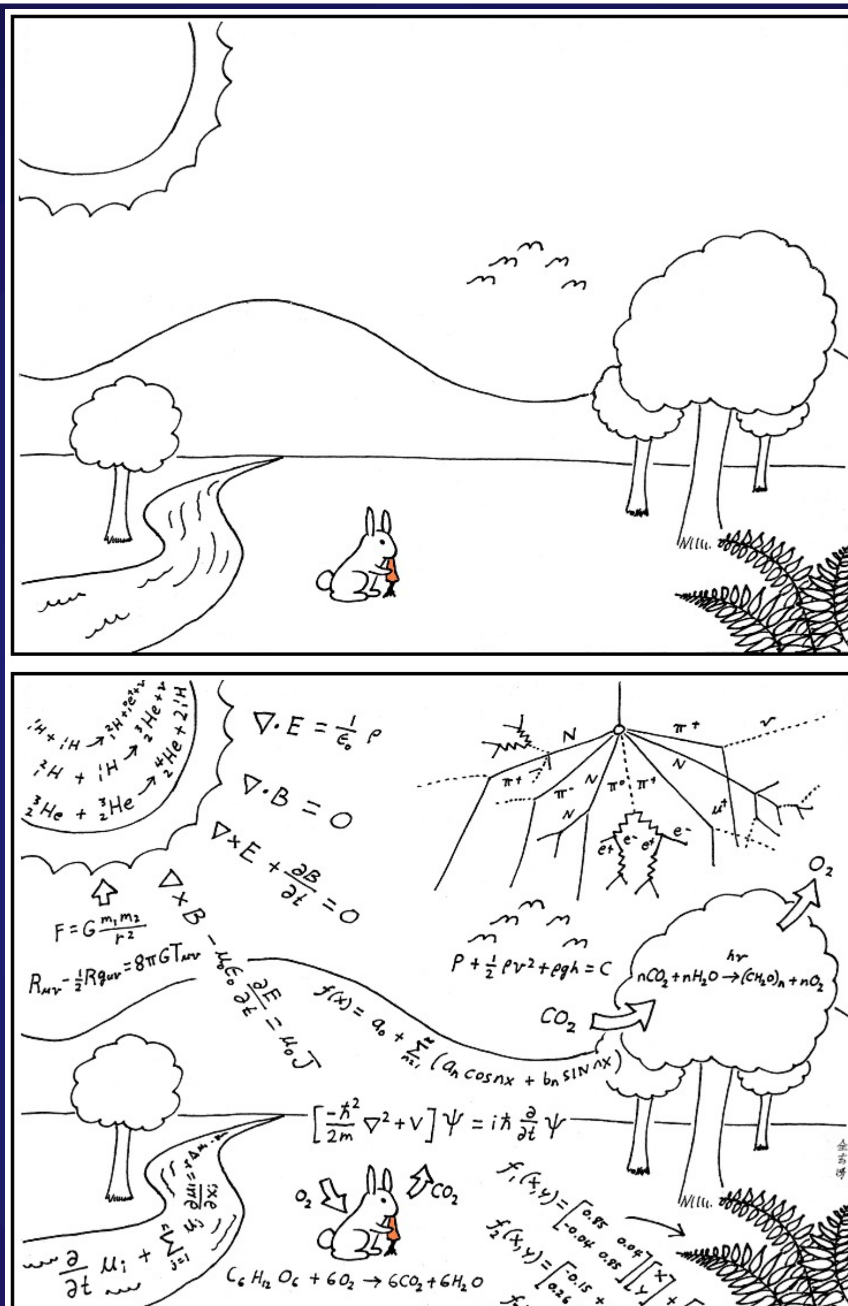
Comets are more ice than rock.



Asteroids are more rock than ice.


http://www.passc.net/EarthImpactDatabase/index.html

"All is number."
-Pythagoras



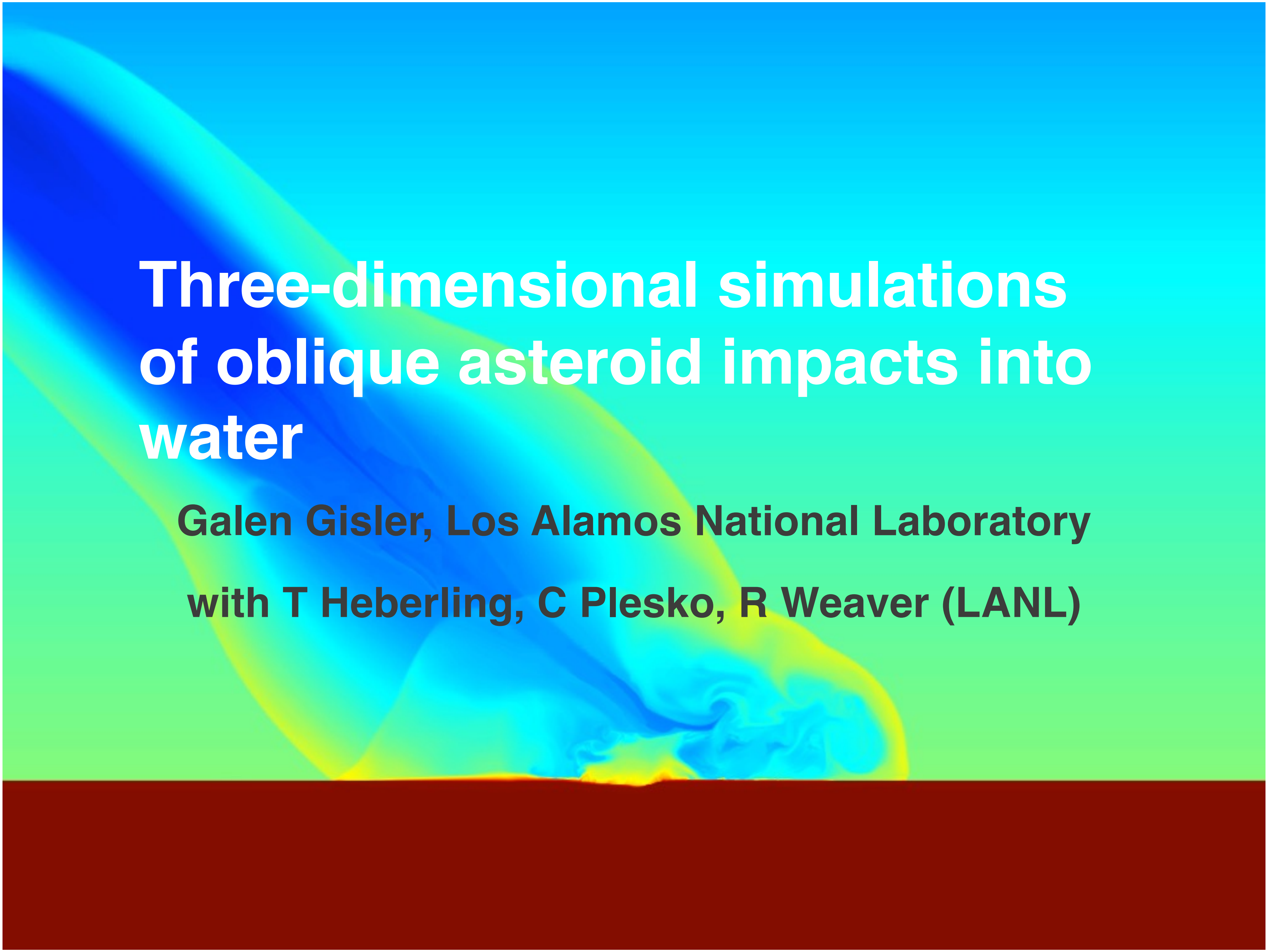
This is how scientists see the world.

Harsh truth courtesy AbstruseGoose.com

Three-dimensional simulations of oblique asteroid impacts into water

Galen Gisler, Los Alamos National Laboratory

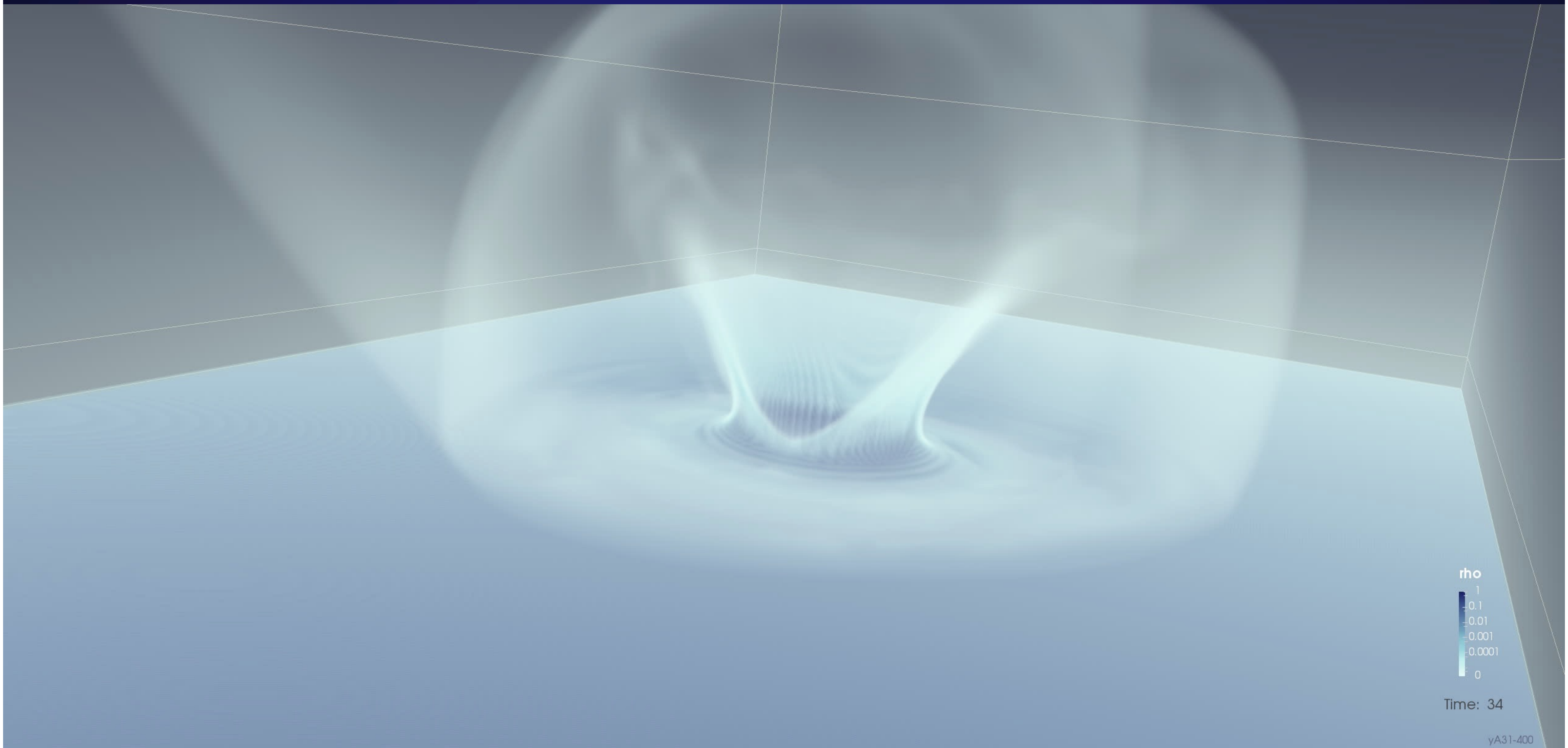
with T Heberling, C Plesko, R Weaver (LANL)



Results on water impacts of small (<300 m diameter) asteroids

- Impacts or airbursts near populated shores are dangerous.
- Impacts far from shore are spectacular and may produce detectable waves at great distances.
- Airbursts over water are less effective at generating waves than impacts into water.
- The most significant effect of an impact into an ocean is the injection of water vapor into the stratosphere, possibly affecting climate.

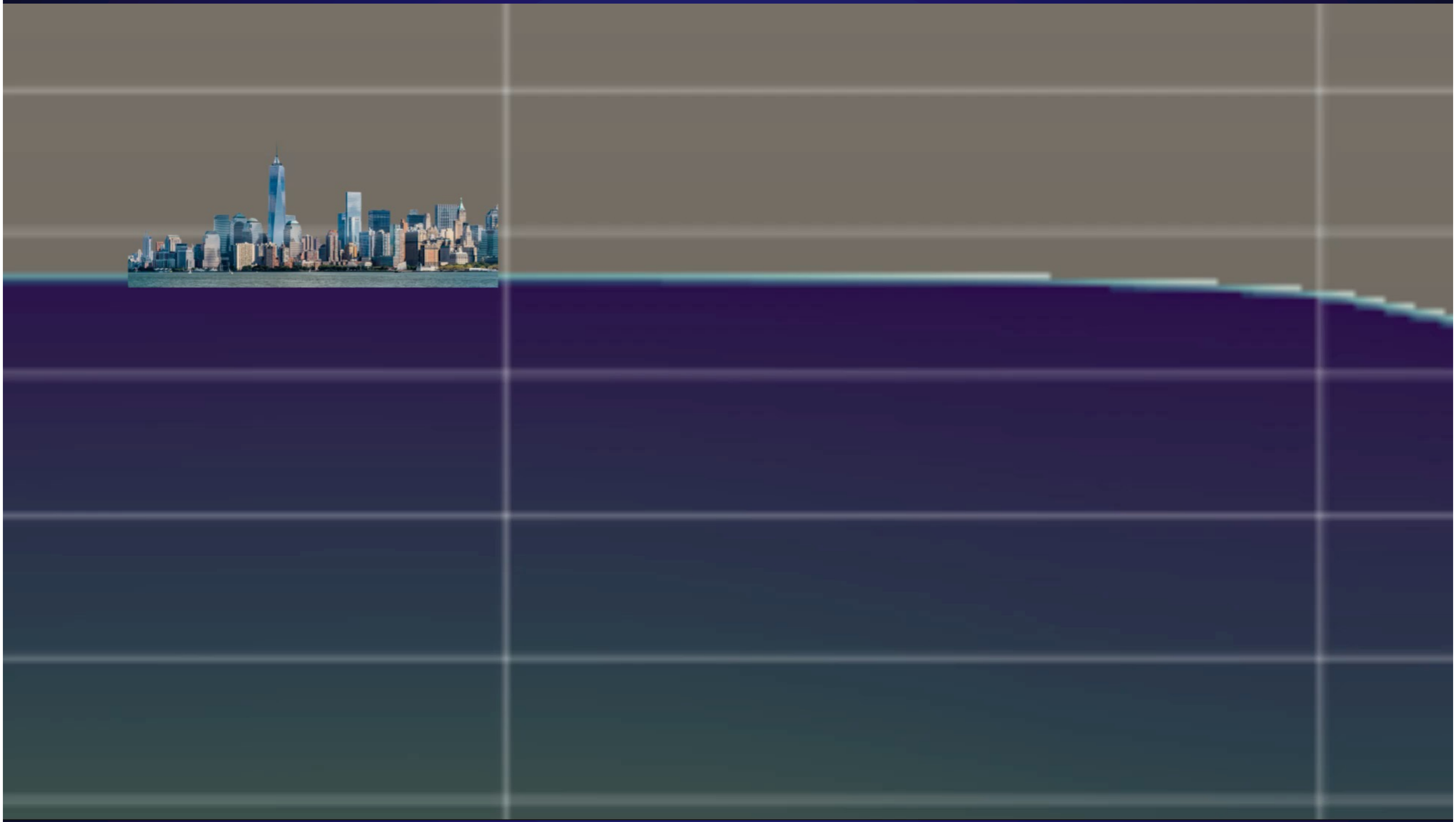
Impact of a 250-meter diameter asteroid into a deep ocean



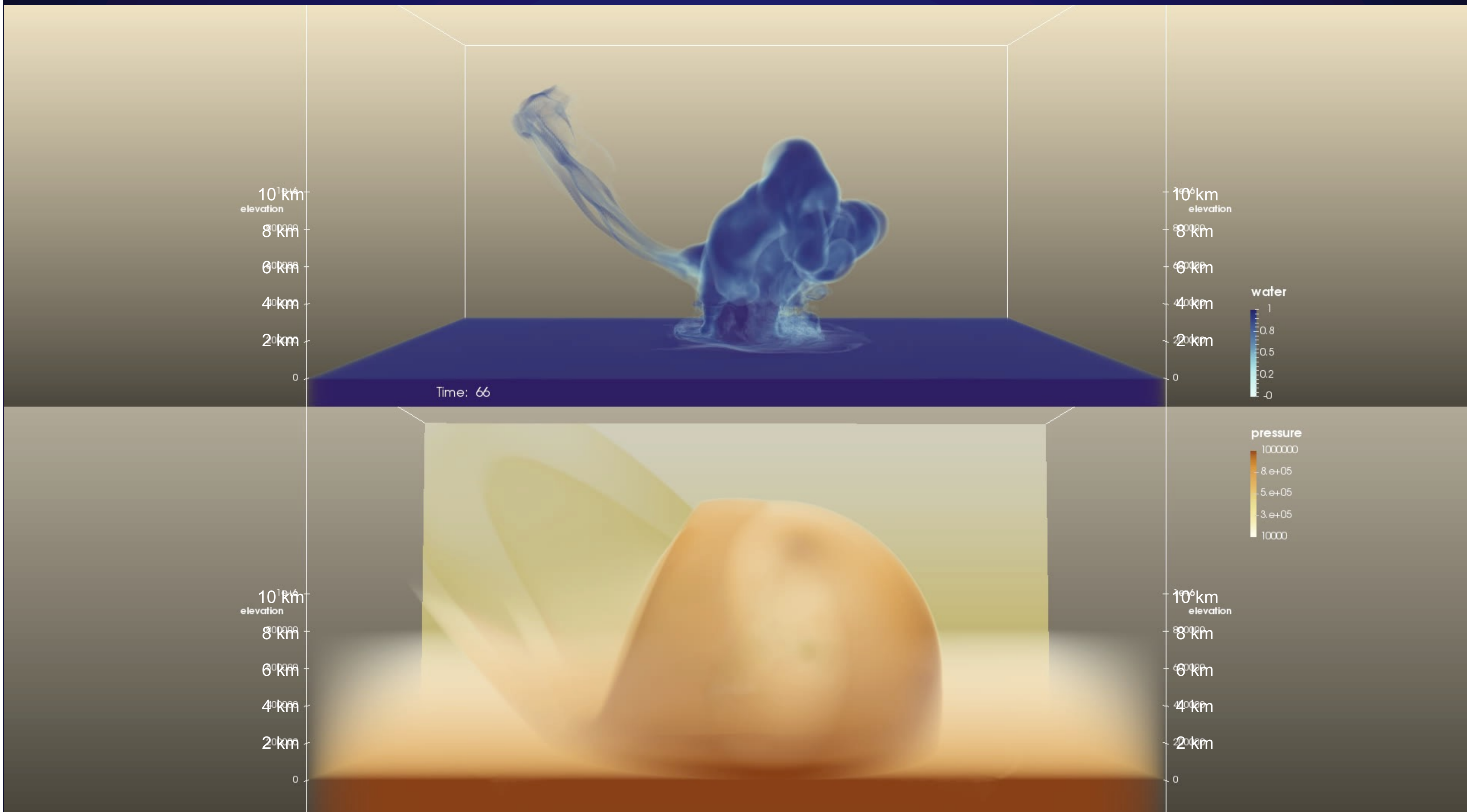
Volume rendering of density.

Visualizations in this presentation were made by a team at Los Alamos (John M. Patchett, David H. Rogers, Boonthanome Nouanesengsy) and University of Texas (Francesca G. Samsel, Karen Tsai, Gregory D. Abram, Terece L. Turton) using simulation data generated by Galen Gisler.

You don’t want to be close to an impact site!



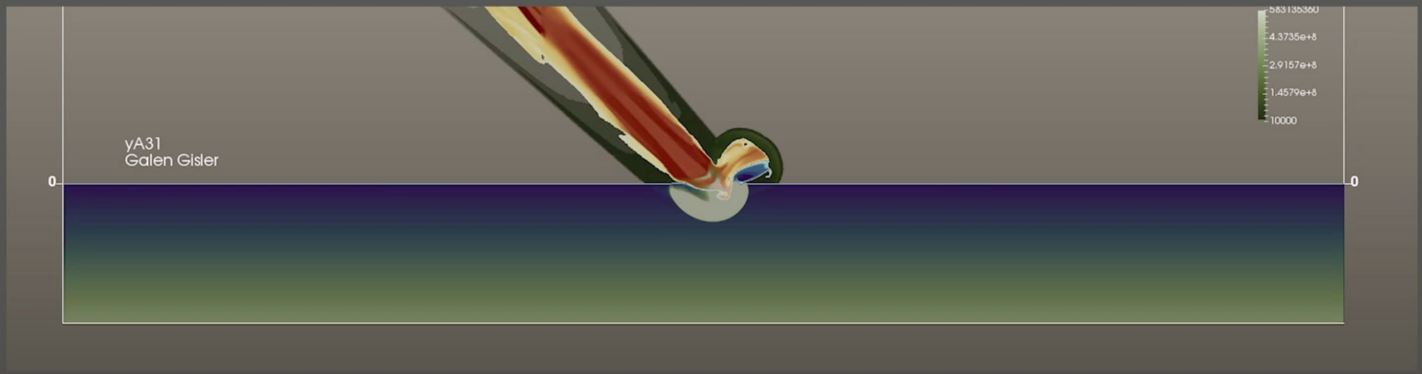
250 m asteroid, no airburst, 45˚ trajectory



Volume rendering of water mass fraction (top) and pressure (bottom)

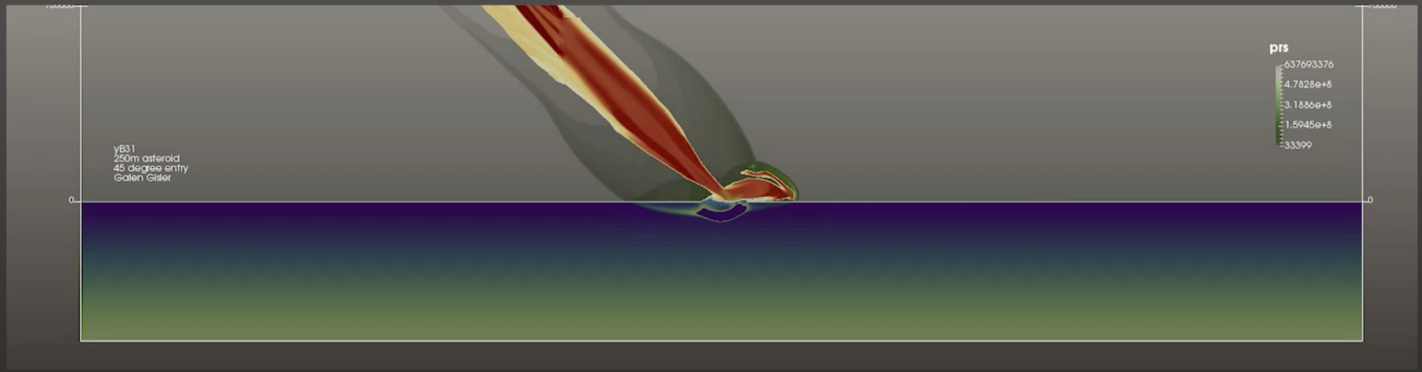
Direct comparison of 3 calculations showing pressure (green), asteroid mass fraction (red), water mass fraction (blue)

yA31



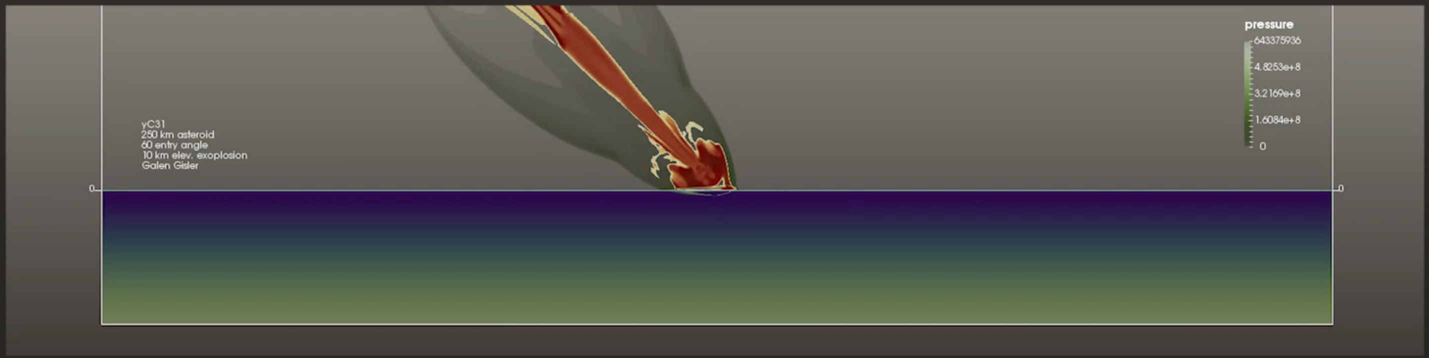
No Airburst

yB31



Airburst at 5km

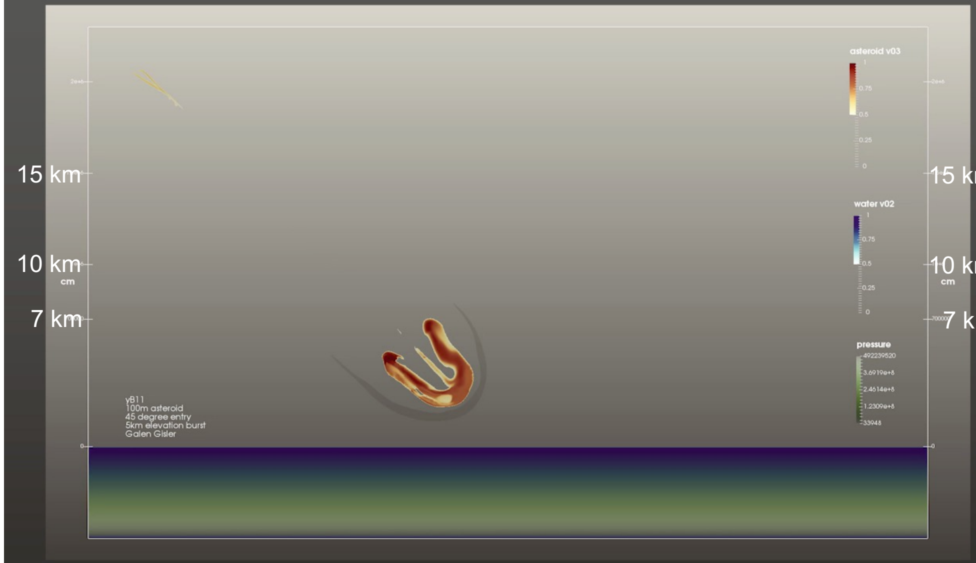
yC31



Airburst at 10km

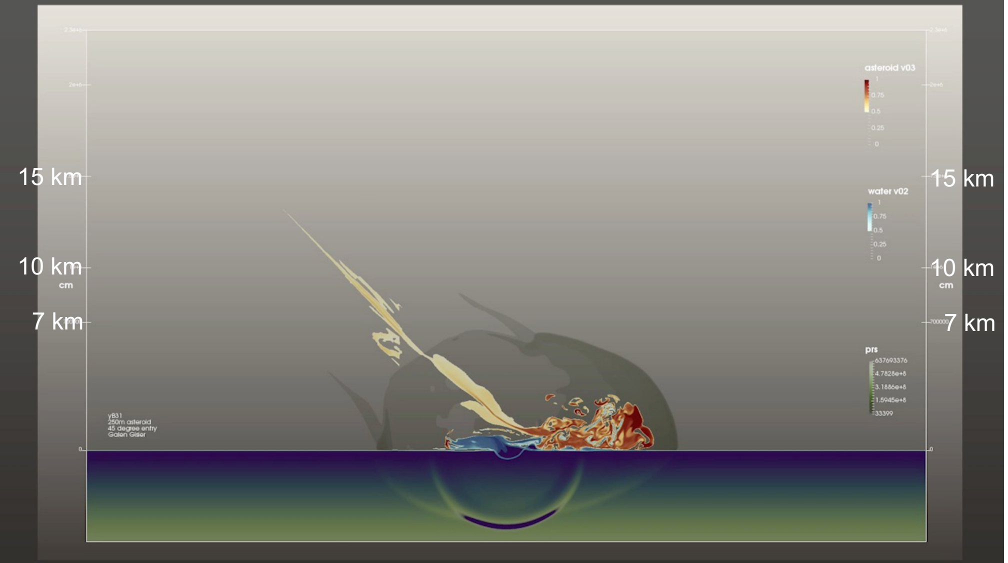
Calculations of different sized impactors

yB11



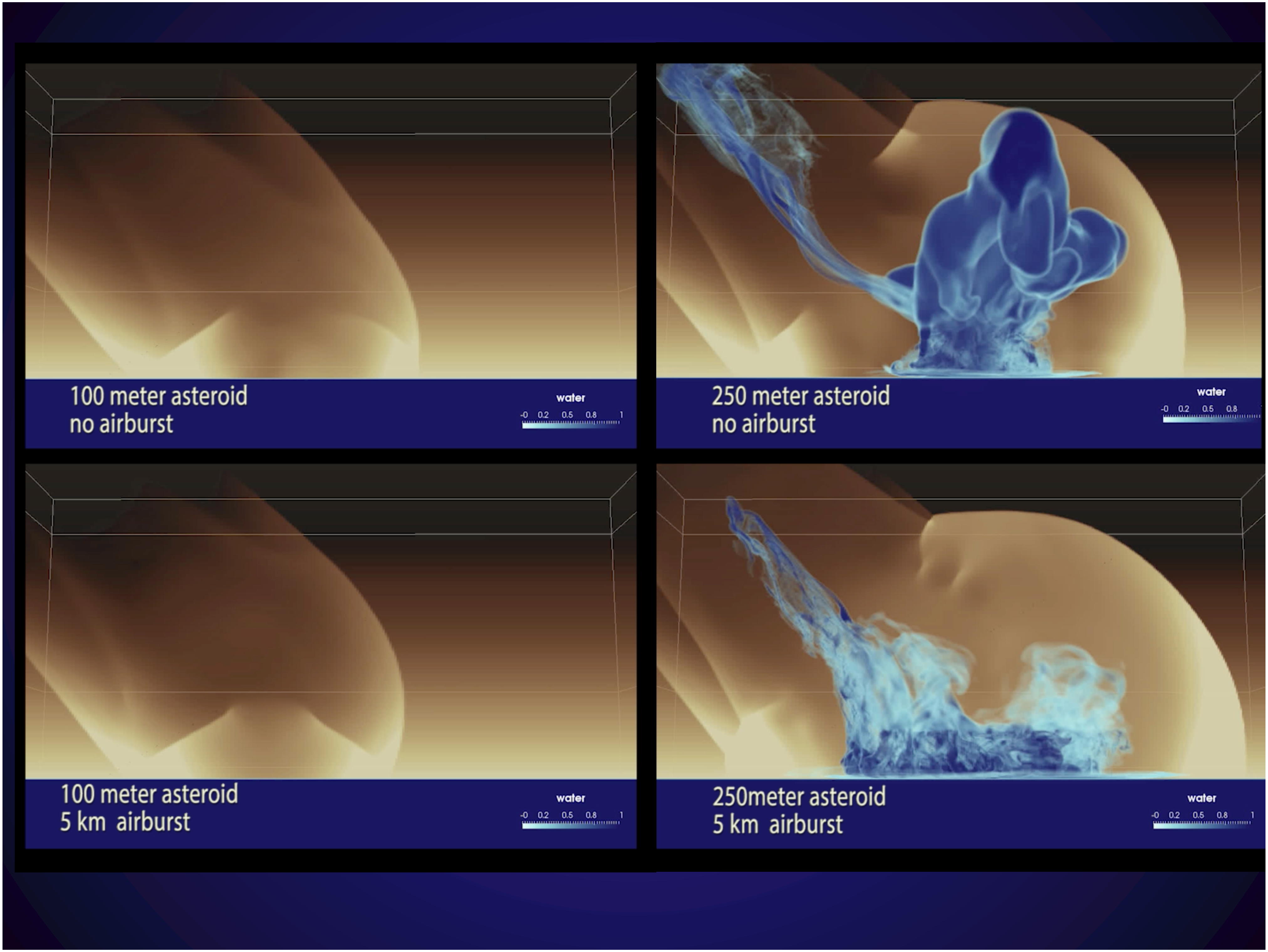
100m Diameter

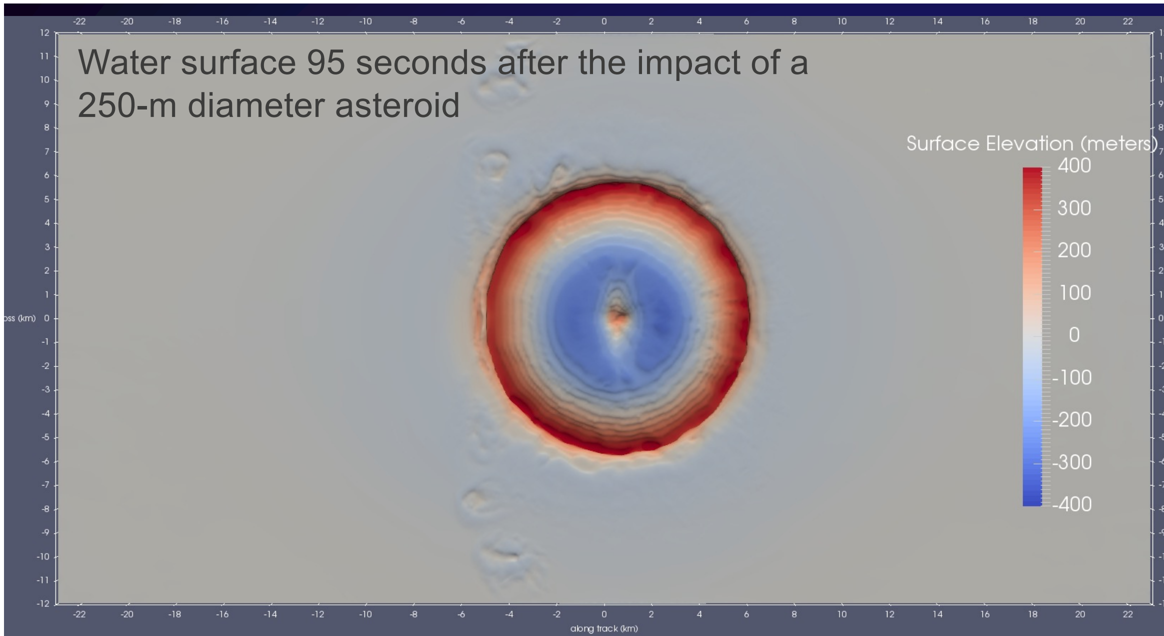
yB31

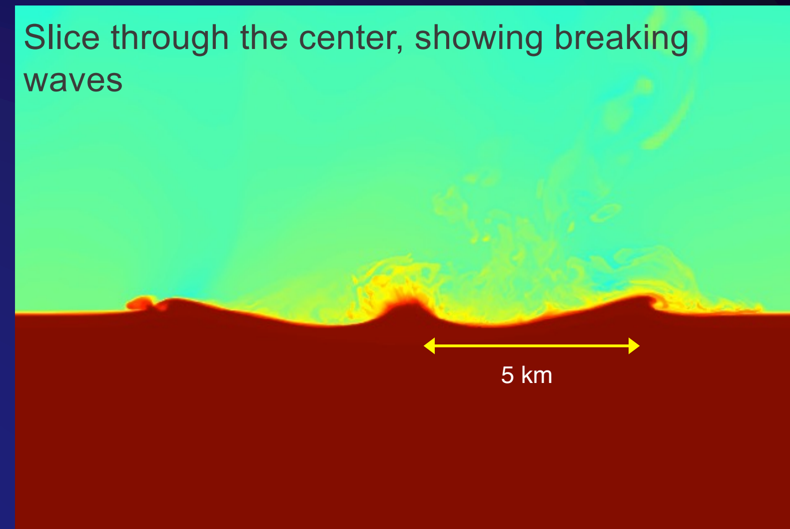


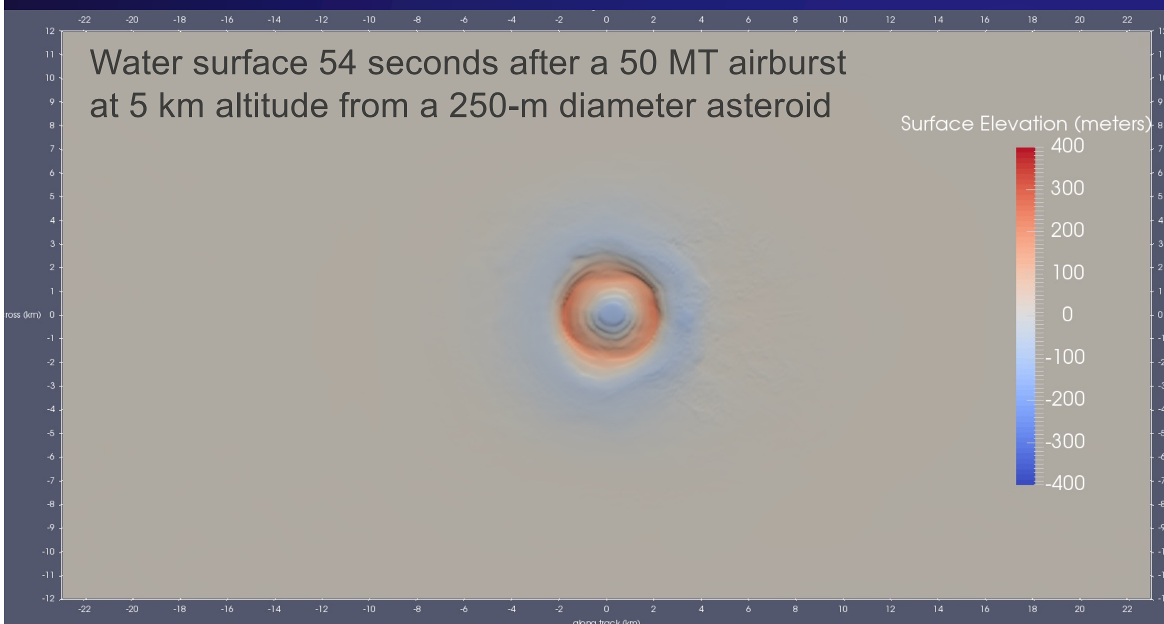
250m Diameter

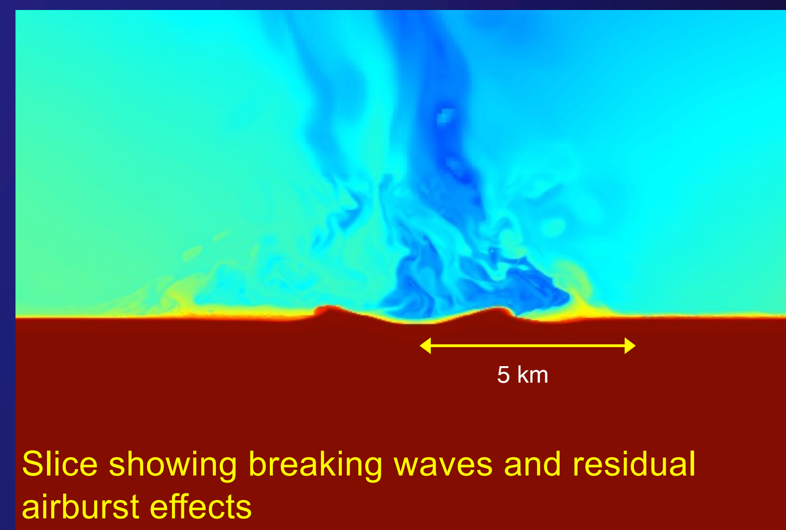
Airburst at 5km
45° Impact Angle


100 meter asteroid
no airburst
water
-0 0.2 0.5 0.8 1
250 meter asteroid
no airburst
water
-0 0.2 0.5 0.8
100 meter asteroid
5 km airburst
water
-0 0.2 0.5 0.8 1
250meter asteroid
5 km airburst
water
-0 0.2 0.5 0.8 1

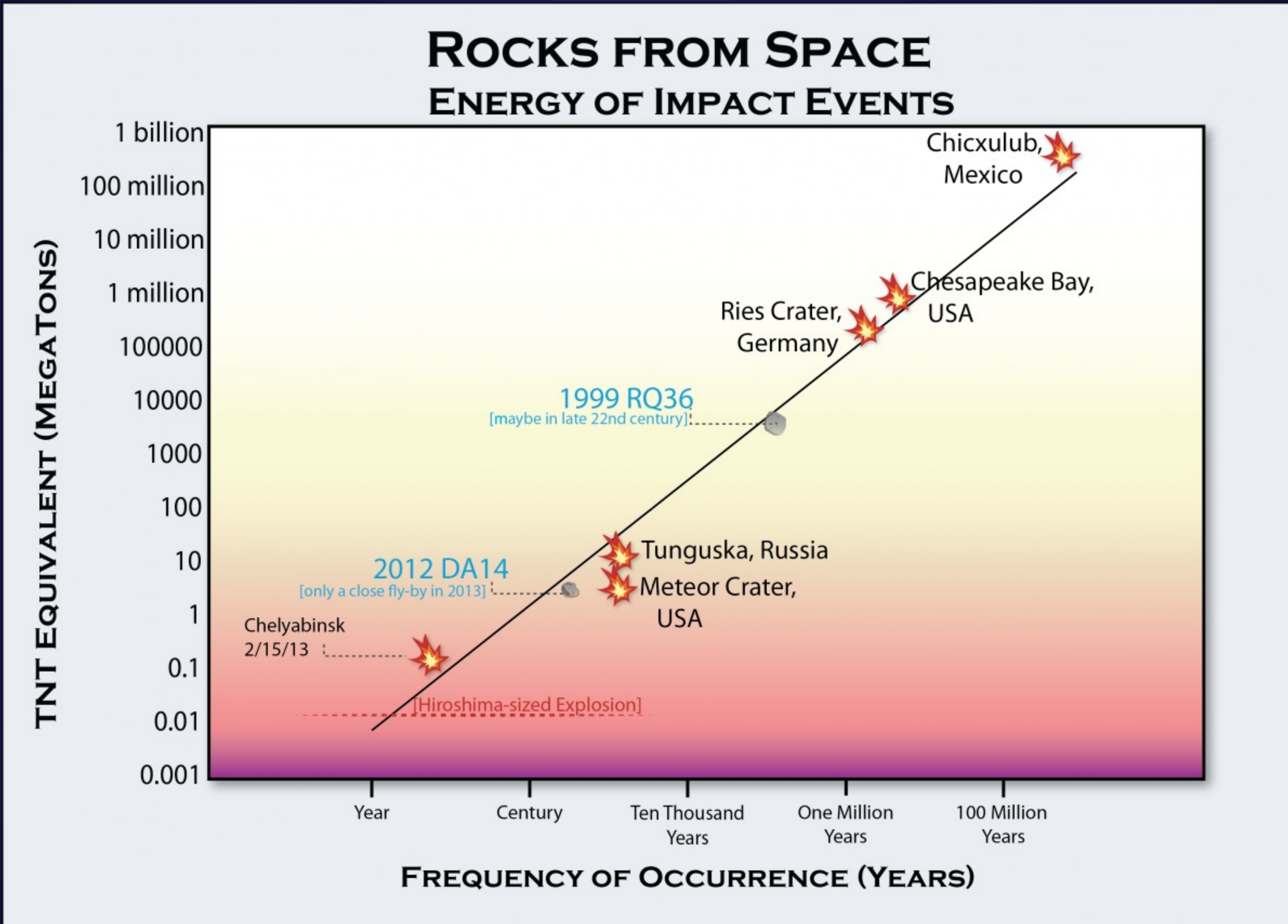








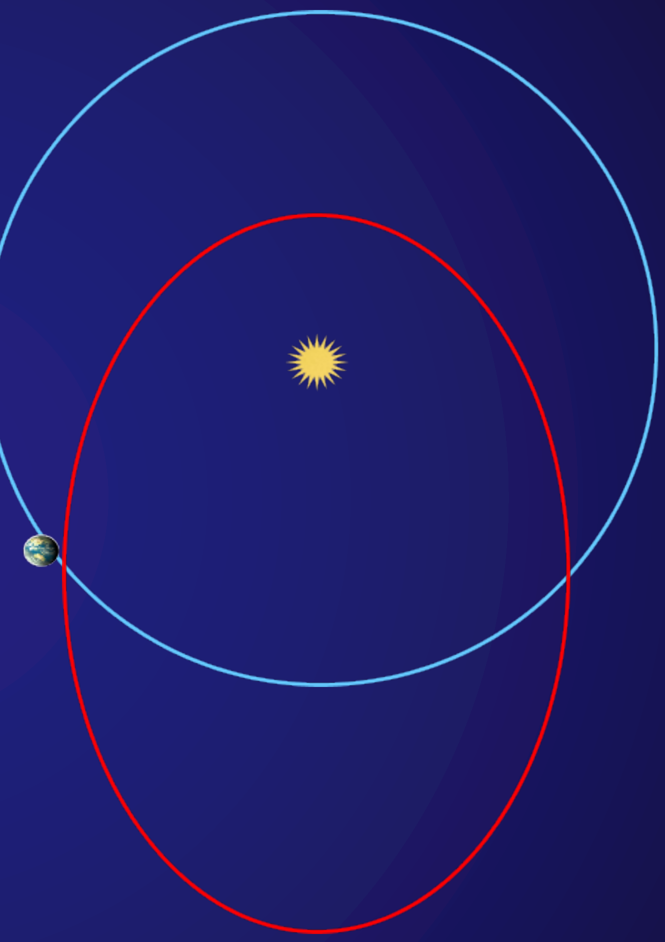
The wavelength of these surface waves is much smaller than typical tsunami wavelengths. They are therefore not expected to propagate efficiently over long distances.



Plot courtesy NASA/OsirisREX

Impact Prevention: Deflection

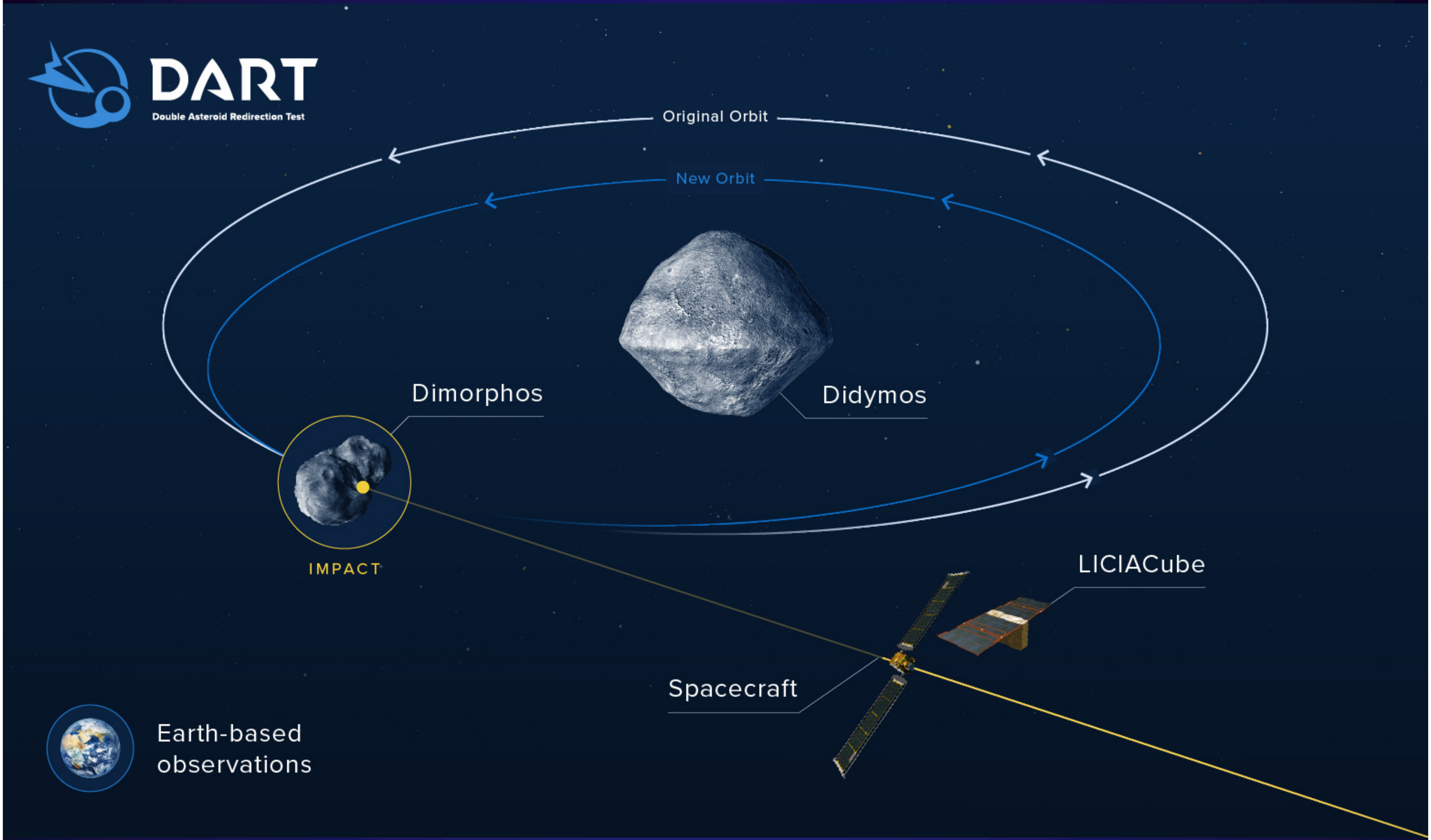
- **Push to alter orbit**
- **Mechanisms:**
  - kinetic
  - explosive
  - light
  - gravity
  - rockets
- **Diameter > 100 m**
- **Reaction time ~ years to decades**



Preventing Impacts: Disrupt and Disperse

- **Fragment**
- **Scatter fragments**
- **Mechanisms:**
  - kinetic
  - explosive
  - mechanical
- **Works best for:**
  - Shorter warning
  - Smaller objects

NASA: Deep Impact Mission

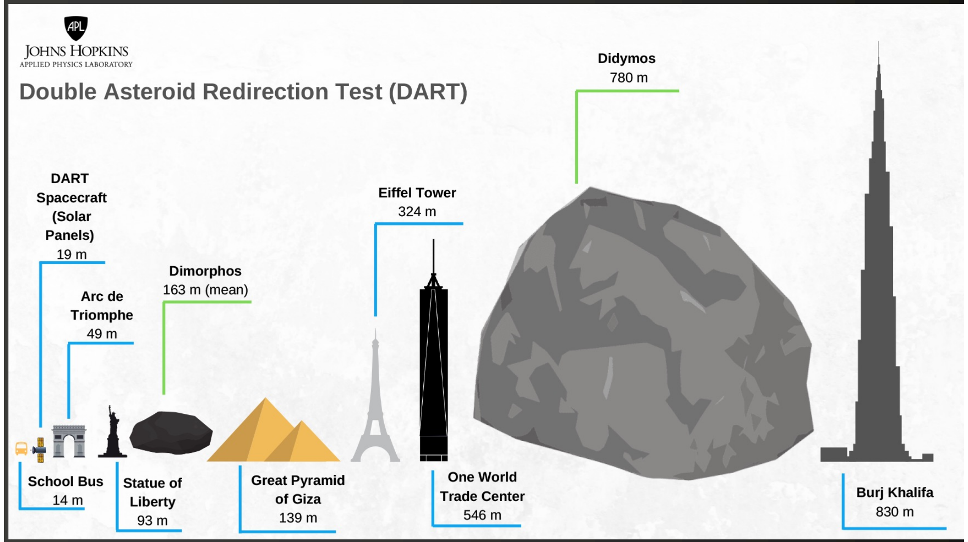


We can test the physics with an experiment

The Target: Asteroid Dimorphos

- Target of the DART kinetic impactor mission
- Smaller member of a binary system
- 100-m-diameter, rocky mixed-type asteroid, 25% porosity
- Tunguska Meteor-sized
- Modeled 4 kinetic impactor scenarios

Model	Impactor Mass [kg]	Impactor Velocity [km/s]	Impact Angle [°]
1	10350.4	19.75	0
2	10350.4	19.75	90
3	7897.0	8.1	0
4	7897.0	8.1	90

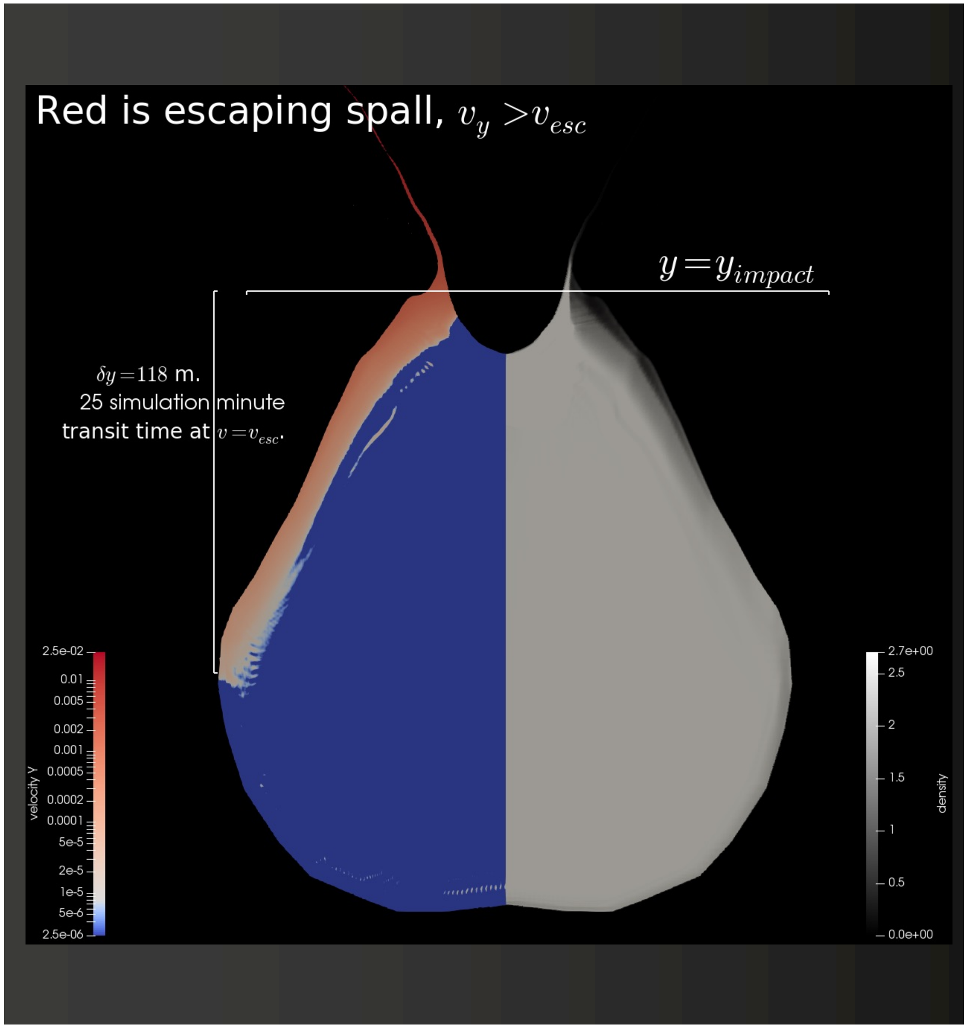


(Figure courtesy NASA/DART)

Computer Model Results

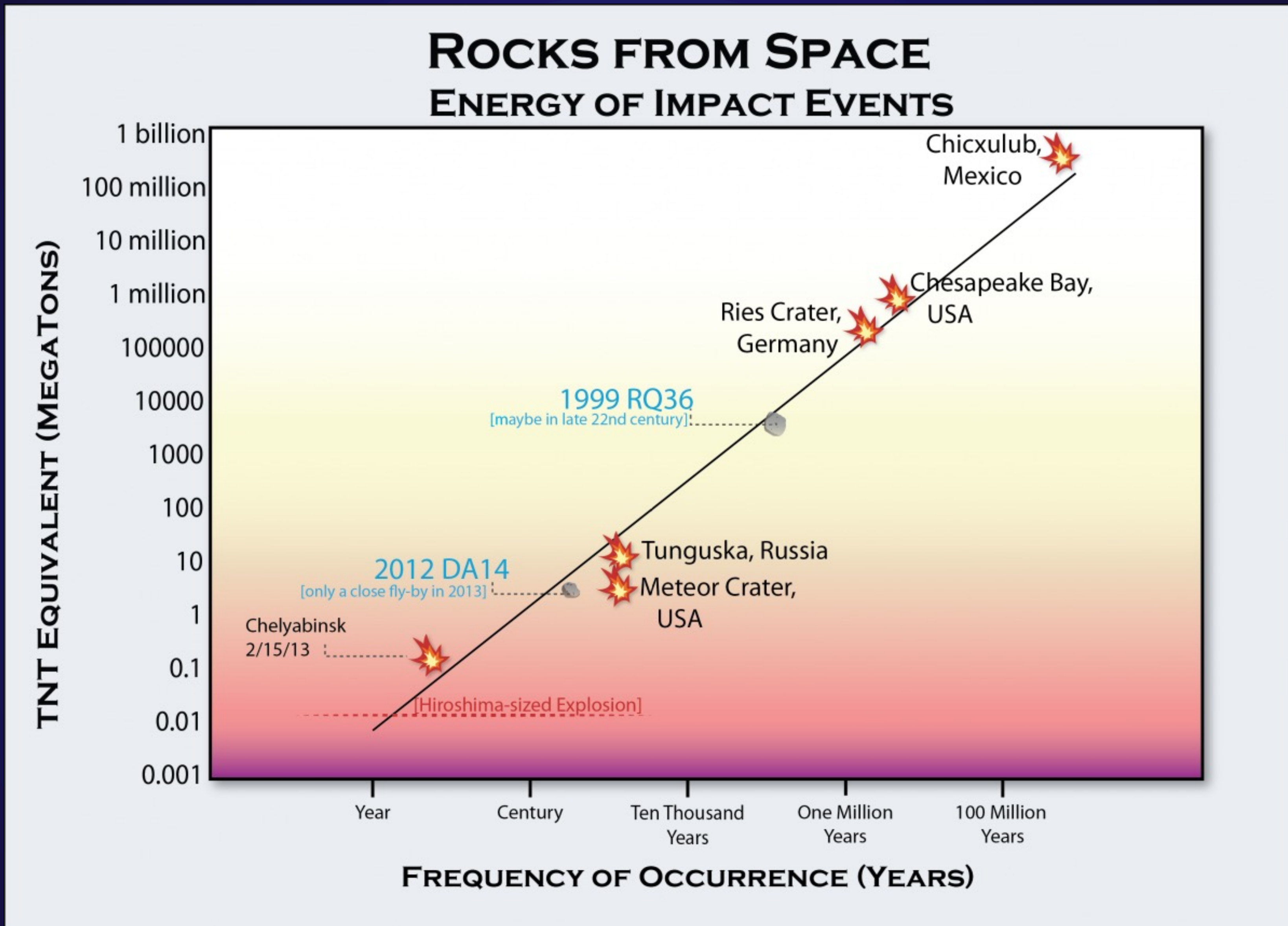
- NASA designed trajectories assuming a perfectly inelastic collision (100% momentum transfer efficiency)
- We estimate 400-2000% momentum transfer efficiency
- Total *system* momentum is conserved
- Spall, shrapnel mean *target mass is not constant*
- So remaining target can have a higher momentum.

Model	m_i [kg]	v_i [km/s]	θ_i [°]	m_{ej} [kg]	β	Δv [cm/s]
1	10350.4	19.75	0	$> 6.7 \times 10^7$	> 7	> 30
2	10350.4	19.75	90	$> 1.2 \times 10^9$	> 17	> 100
3	7897.0	8.1	0	8.2×10^8	21	36
4	7897.0	8.1	90	1.3×10^8	20	38

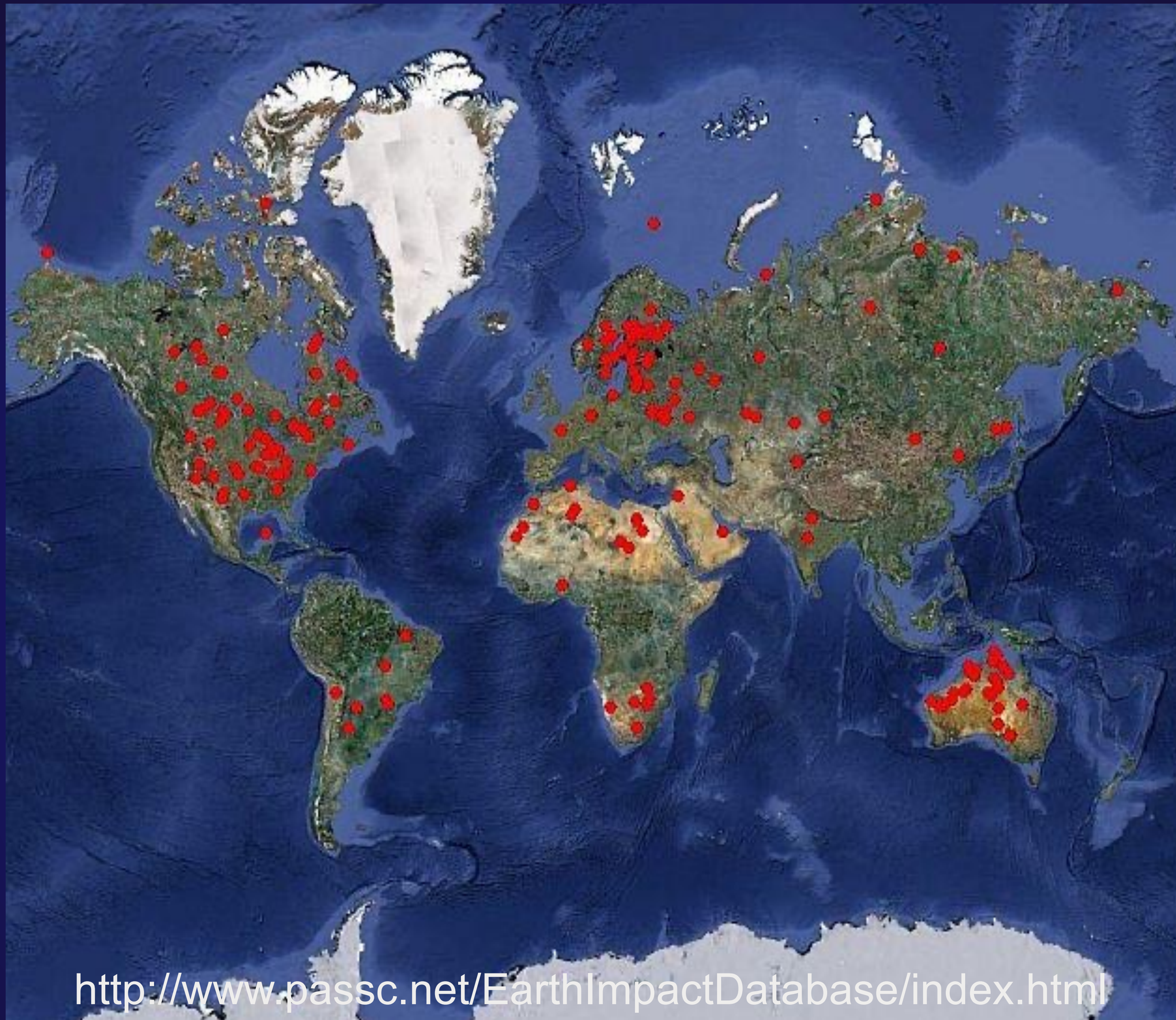


Questions?

How often do impacts happen, and how do we know that, exactly?

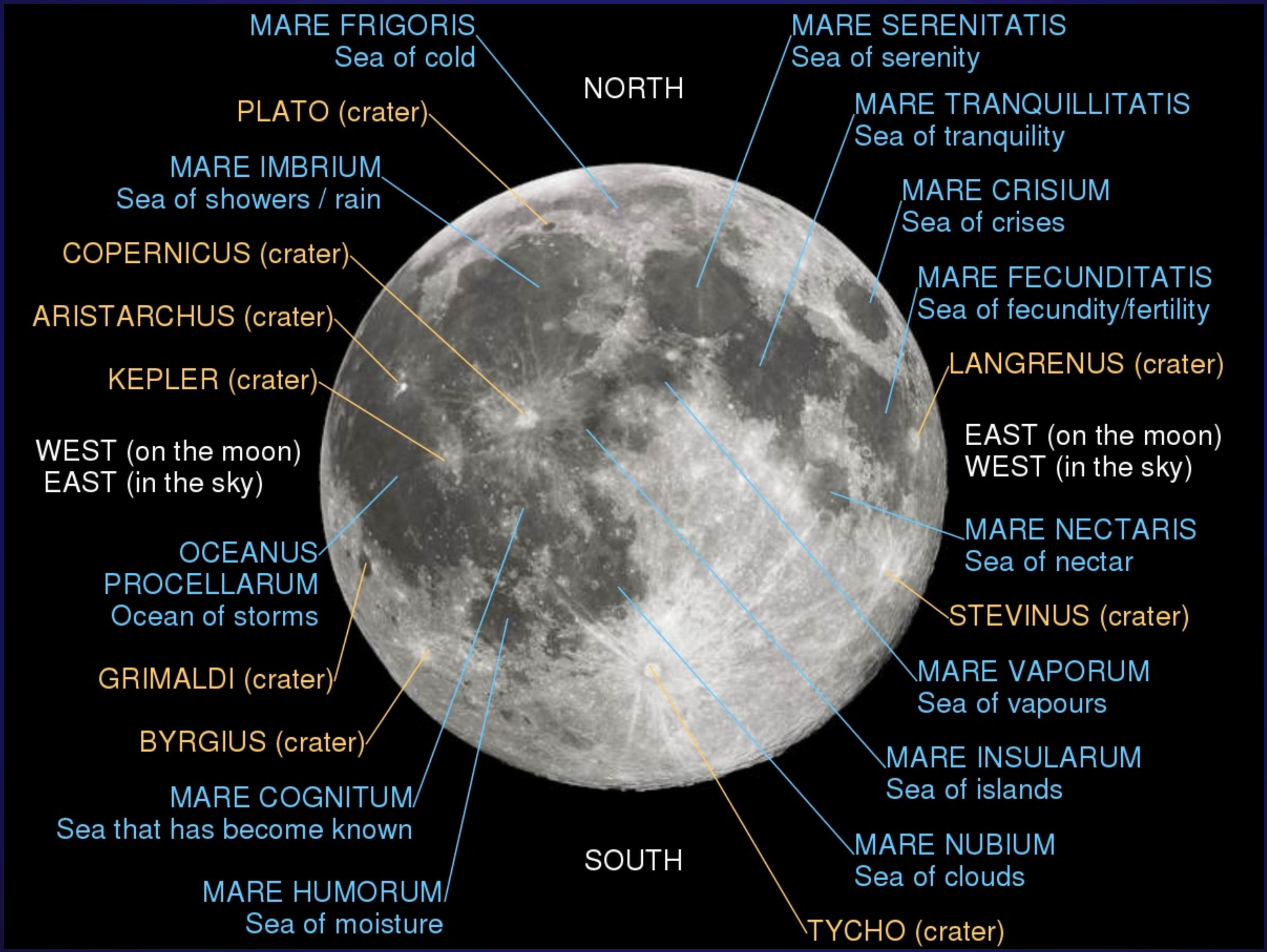


Plot courtesy NASA/OsirisREX


http://www.passc.net/EarthImpactDatabase/index.html

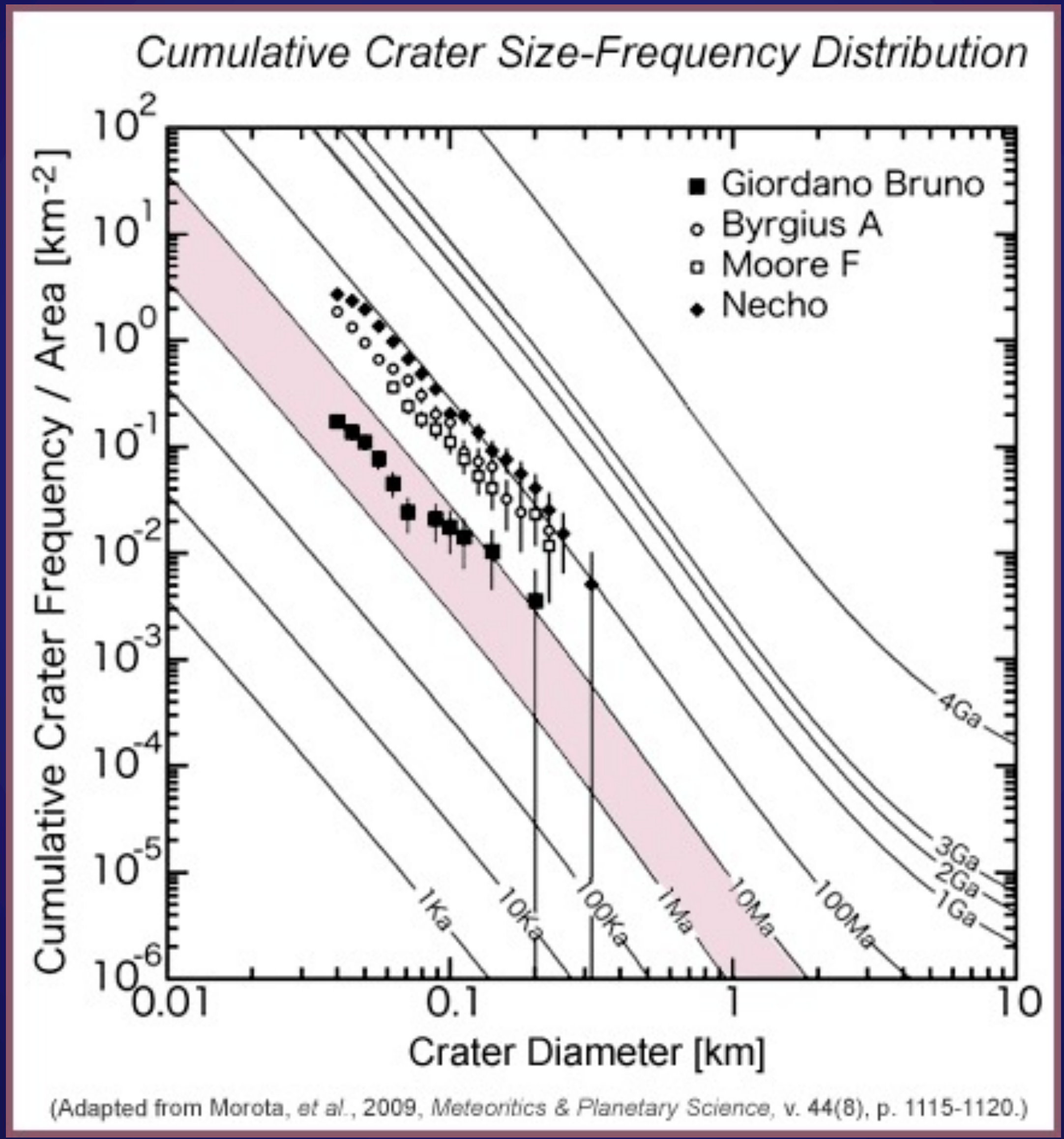
The Moon: No plate tectonics or liquid water.

Scientists count the craters



The age of rocks collected on the Moon were estimated from radioactive decay of the minerals.

Then we know how many there are of a given size, and how old they are.

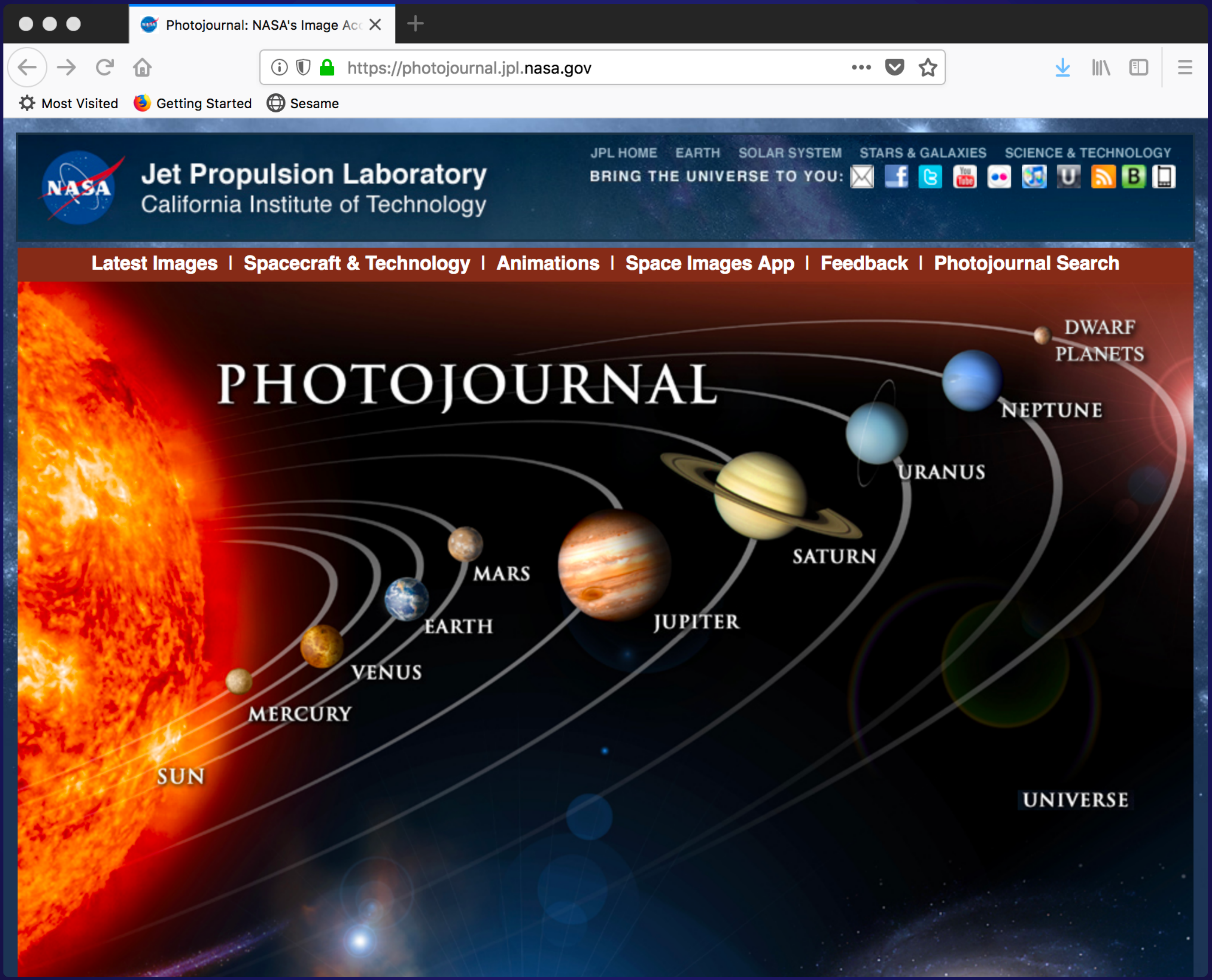


If you know that, you can estimate how often objects of a given size hit the Moon (and the Earth).

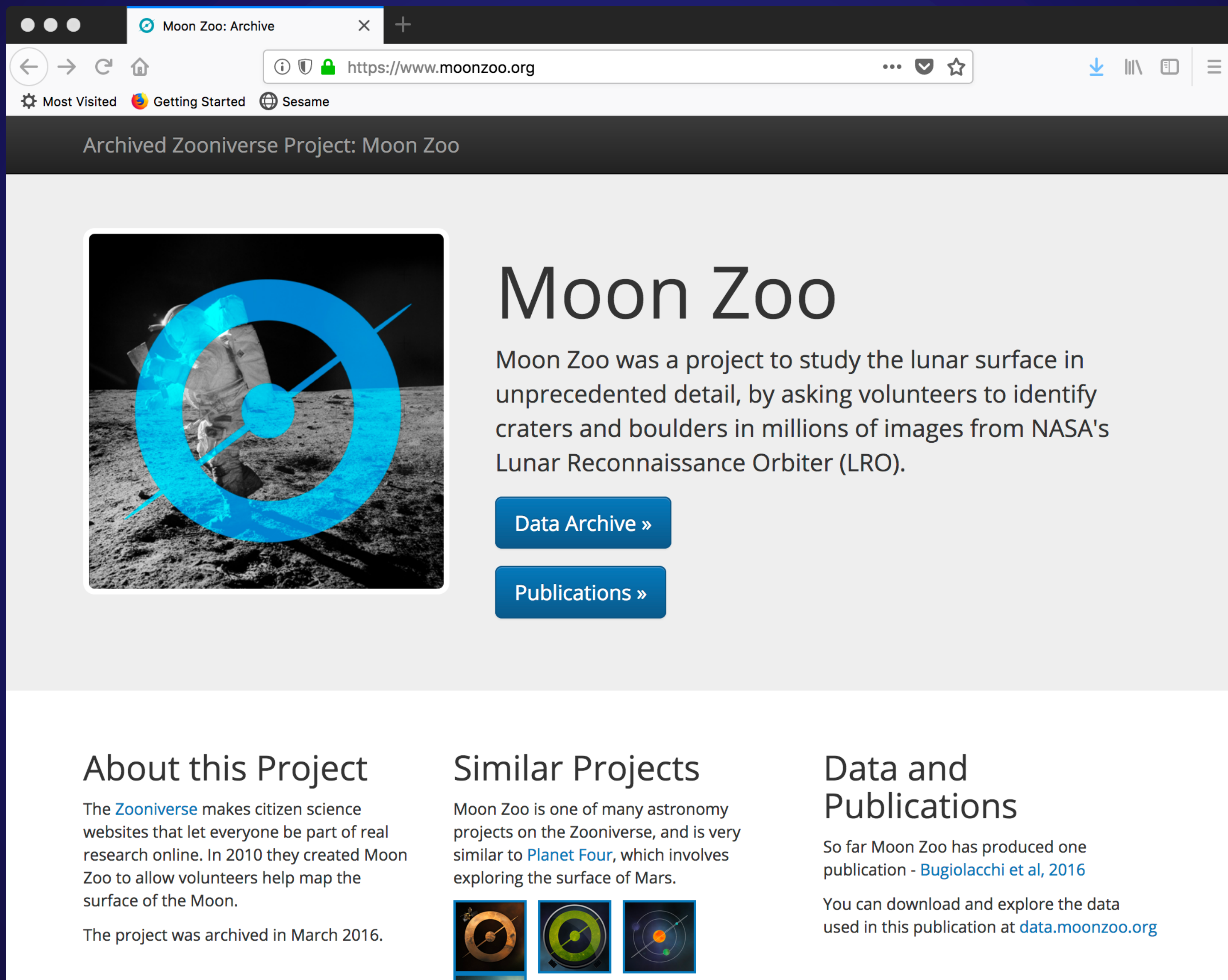
But…

Little asteroids hit less often than big ones, and all the big craters have been counted.

Fortunately, there's plenty of data



Some projects use crowdsourcing



Some projects use machine learning

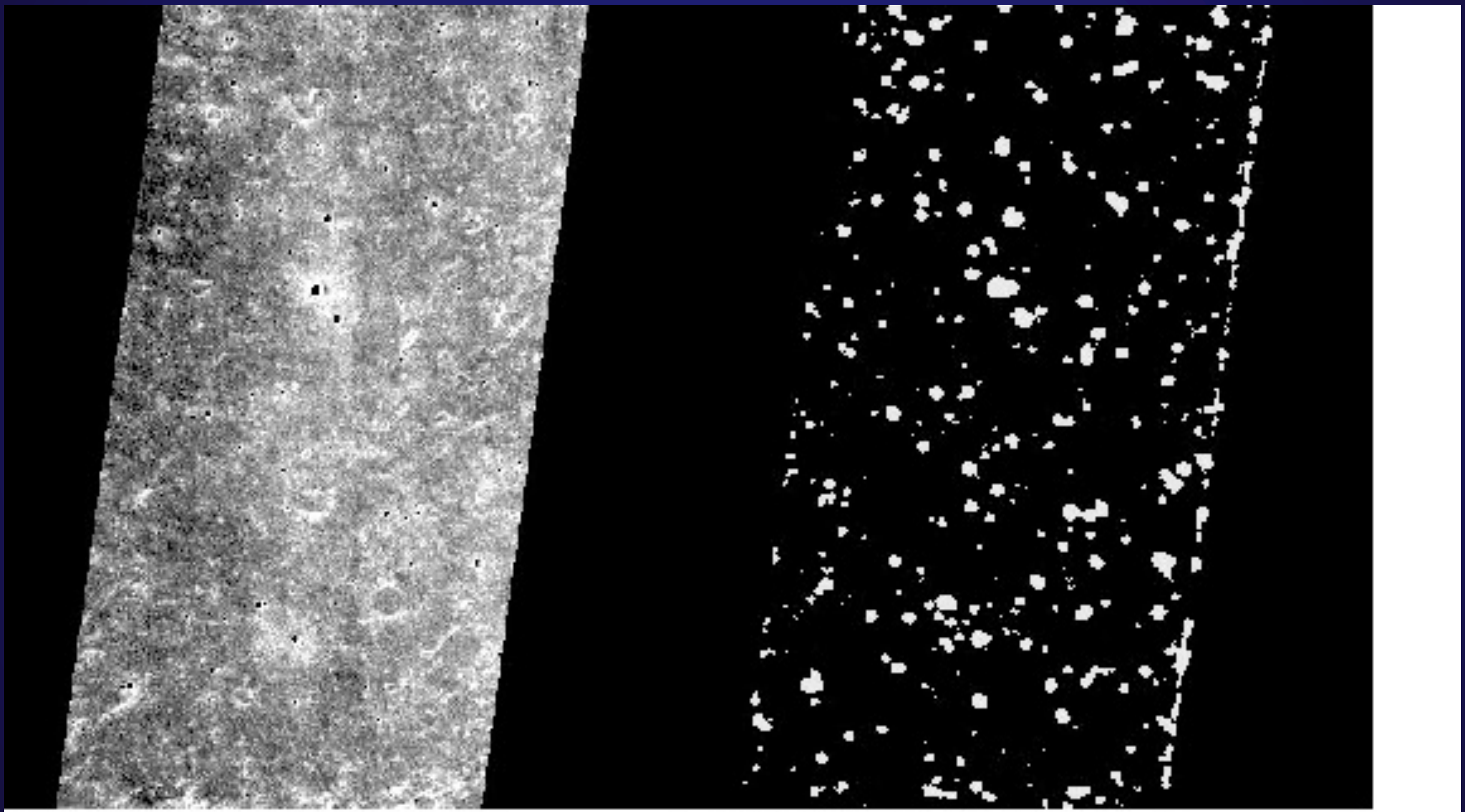


Figure 2. MOC Image M0803054: Test Scene 1, re

Modern automated counts still haven't beaten simple hand-programmed counting scripts

Clark Chapman wrote the first automated crater counting script more than 40 years ago.

What would you do?

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